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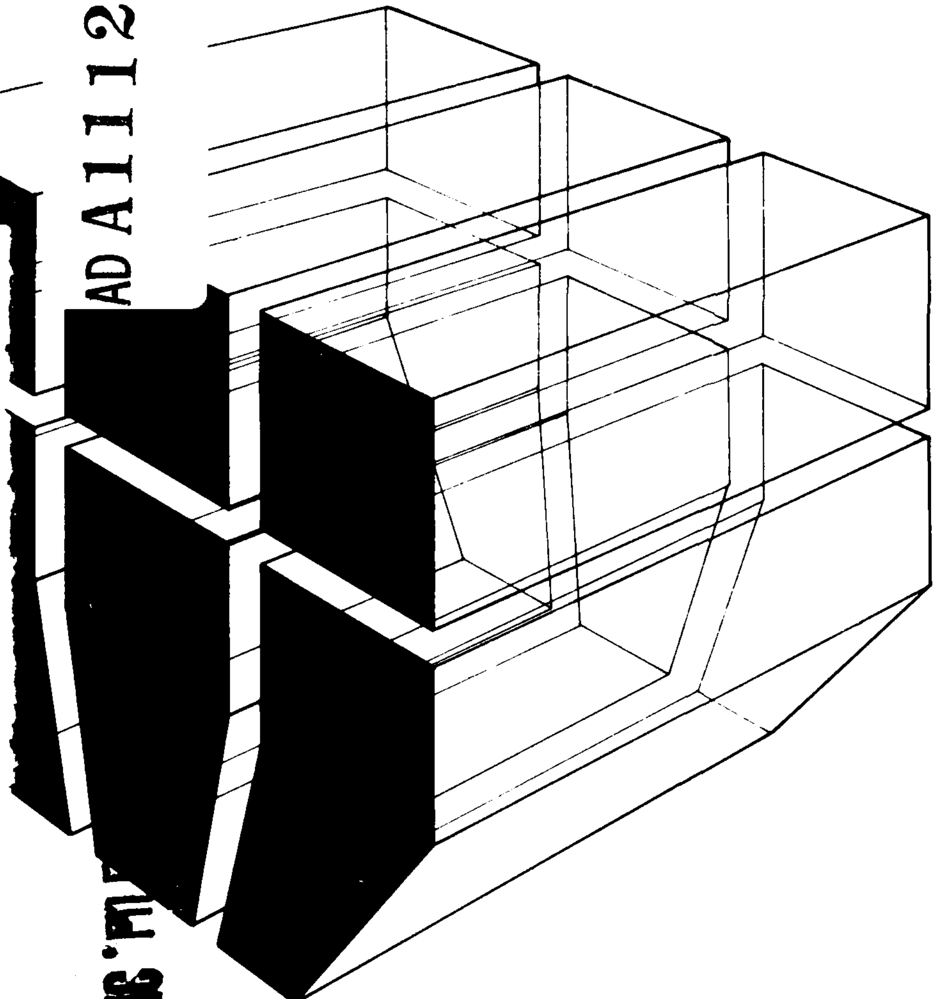
Technical Report N-116
November 1981
Interdependency of Elements in Ecological Systems

EFFECTS OF TACTICAL VEHICLE ACTIVITY ON THE MAMMALS, BIRDS, AND VEGETATION AT FORT LEWIS, WASHINGTON



by
W. D. Severinghaus
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A field study was conducted at Fort Lewis, WA, to investigate the effects of Army tracked vehicle training on the resident mammal, bird, and plant populations. This report: (1) describes preliminary indications of ecological differences between selected areas used for vehicle training and areas undisturbed by training, (2) documents the procedures used to obtain this information, and (3) analyzes Fort Lewis' ecosystem to verify the effects of training activities on ecosystems examined in previous research.

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FOREWORD

This investigation was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL) under Work Unit AT23-C-001, "Interdependency of Elements in Ecological Systems." The vegetation study was conducted by Oscar H. Soule of Evergreen State College, Olympia, WA. The authors would like to acknowledge the field assistance of Mary C. Severinghaus. Dr. R. K. Jain is Chief of EN.

COL L. J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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EFFECTS OF TACTICAL VEHICLE ACTIVITY ON THE MAMMALS, BIRDS, AND VEGETATION AT FORT LEWIS, WASHINGTON

1 INTRODUCTION

Background

Recent trends in environmental impact analysis require that impact estimates be quantified; using analytical models is one effective way of doing this. But because appropriate cause/effect relationships between Army activities and their impacts on ecosystems have not yet been established, ecological modeling is not now feasible.

This report is the third of a series documenting basic ecological research conducted to establish these relationships. The first two reports described the effects of tracked vehicle activity on the ecosystems of Fort Knox, KY, and Fort Hood, TX.[1] Further significant findings will be documented as they occur during later research, which will study quantification of impacts on soil, water, and additional ecosystem compartments.

Objective

The overall objective of this study is to determine Army activities' effects on ecosystems. The objectives of this report are: (1) to describe preliminary indications of ecological differences between selected areas used for Army tracked vehicle training and areas undisturbed by training, (2) to document the procedures used to obtain this information, and (3) to analyze Fort Lewis' ecosystem to verify tactical vehicle cause/effect relationships established in previous research.

Approach

Intensive field surveys were conducted at selected sites at Fort Lewis, WA, to establish the effects of tracked vehicle training on birds, small mammals, and vegetation.

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[1] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA073782 (U.S. Army Construction Engineering Research Laboratory [CERL], July 1979); W. D. Severinghaus and W. D. Goran, Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX, Technical Report N-113 (CERL, September 1981).

2 GENERAL SITE DESCRIPTION

Two upland prairie sites were chosen for studying the effects of tracked vehicles on the biota at Fort Lewis, WA (Figure 1). The 13th Division Prairie site lies in the eastern portion of the military reservation (T18N, R3E, Section 20, NW1/4; Pierce County, Washington, 132-m) elevation. The Johnson Prairie site lies in the southwestern portion (T17N, R1E, Section 30, SW1/4; Thurston County, Washington, 132-m) elevation. Historically, the sites are similar in geology, biota, and aboriginal and modern use. The 13th Division Prairie site has been used more over the past decade than the Johnson Prairie site. Thus, the 13th Division Prairie was chosen as the disturbed site and Johnson Prairie as the control. It should be noted that no prairie in western Washington represents the undisturbed biotic community found by early American settlers from 1800 to 1825.

Although the prairies of western Washington have not received extensive botanical attention,[2] they are a conspicuous feature of the landscape of the south Puget Sound region.[3] While these grasslands may not meet the classic definition of prairie,[4] certainly they are naturally occurring plant communities with a distinct endemic flora. The prairie vegetation is unusual because it is primarily xeric, yet is surrounded by species adapted to the mesic conditions of western Washington's coniferous forests.[5]

The 13th Division Prairie Site

The 13th Division Prairie site is on the gravel outwash plains of the Vashon Glacier, which covered the area 13,500 to 15,000 years before the present (BP).[6] This final glacial period gave the prairies their characteristic topography, only slightly modified by post-glacial erosion.[7]

The site lies in the drainage of Muck Creek, which flows into the Nisqually River; the soil is a well-drained gravel. The lack of erosion

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[2] R. Del Moral and D. Deardorff, "Vegetation of the Mima Mounds, Washington State," Ecology, Vol 57 (1976), pp 520-530.

[3] J. F. Franklin and C. T. Dyrness, Natural Vegetation of Oregon and Washington, U. S. Department of Agriculture (USDA) Forest Service General Technical Report PNW-8 (1973), 89 pp.

[4] F. A. Lang, A Study of Vegetation Change on the Gravelly Prairies of Pierce and Thurston Counties, Western Washington (M. S. Thesis, University of Washington, 1961), p 2.

[5] S. Klotz and D. Smith, Distribution of Plant Species on the Mound of Mima Prairie, Thurston County, Washington, in S. G. Herman and A. M. Weidman, eds. Contributions to the Natural History of the Southern Puget Sound Region, Washington (Olympia, Washington: The Evergreen State College, 1975).

[6] B. McKee, Cascadia, The Geologic Evolution of the Pacific Northwest (McGraw-Hill Book Company, 1972).

[7] Lang, p 7.

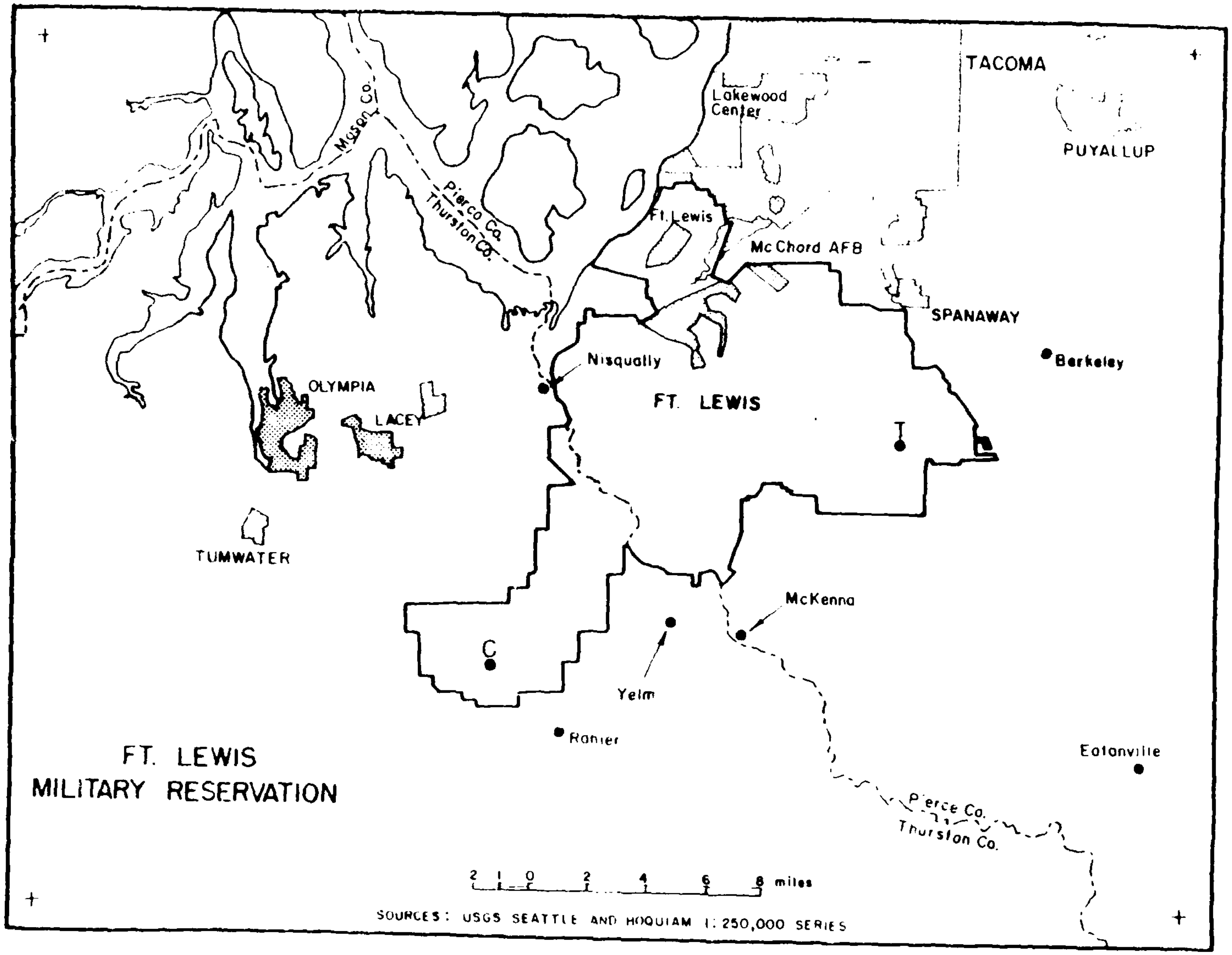

Figure 1. Study sites at Fort Lewis, WA (T = test site, 13th Division Prairie; C = control site, Johnson Prairie).

channels shows that the soil is capable of handling the rainfall, which is about 900 mm/year, compared with 1280 mm in Olympia.[8]

The prairie soils of western Washington are collectively called the Spanaway Series.[9] The soil is very droughty because little water is held in the root zone during the growing season, internal drainage is rapid, and the zone of root penetration is about 450 mm.[10] The low productivity of the soils results mainly from their low fertility.

Based on pollen records, it appears that the prairies took on their current appearance during the hypsothermal period of 6000 BP.[11]

The test site was 500 to 700 m south of Muck Creek. This creek is bordered by a riparian community dominated by large black cottonwood (Populus angustifolia) about 20-m high, 15-m Oregon ash (Fraxinus latifolia), and 7-m willows (Salix sp). Other woody plants form a dense thicket along the creek. These include cascara (Rhamnus purchiana), western hazelnut (Corylus cornuta), Nootka rose (Rosa nutkana), red elderberry (Sambucus racemosa), Pacific ninebark (Physocarpus capitatus), common snowberry (Symphoricarpus albus), and western serviceberry (Amelanchier alnifolia).

The riparian forest is a band about 5- to 10-m wide on both sides of the creek. On the south side, the forest is bordered by a sward of nonnative grasses. The dominant species, Kentucky bluegrass (Poa praetensis), common velvet grass (Holcus lanatus), English rye (Lolium perenne), and orchard grass Dactylis glomerata) create a stand 3-m high and 10-m wide that follows the flood plain of the creek.

This grassy belt grades into the "true" prairie, an area shaped like a circle roughly 2 km in diameter. The prairie has scattered clumps of Oregon white oak (Quercus garryana) and Scotch broom (Cytisus scoparius). There were no trees or shrubs in the sampling site selected; ten 1-m^2 quadrats were randomly chosen. Density, frequency, and biomass were determined for each.

A walking survey showed that 62.2 percent of the prairie was covered by vehicle tracks of various ages.

Johnson Prairie Site

Johnson Prairie lies in the drainage of the Deschutes River, which, like the Nisqually River, flows into southern Puget Sound. Topographic, edaphic, and climatologic features of the Johnson Prairie are similar to those discussed for the 13th Division Prairie Site.[12]

The Johnson Prairie, an isolated, western extension of the Wier Prairie, is surrounded by groves of Douglas fir 15- to 30-m tall. There are small Douglas fir, less than 2-m tall, toward the edge of the prairie. (These are

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[8] Lang, p 71.
[9] Lang, p 66.
[10] Lang, p 66.
[11] Lang, p 69.
[12] Lang.

generally associated with site disturbances, such as foxholes.) Thus, the forest seems to be advancing onto the prairie.

The sampling site on the Johnson Prairie is a slightly undulating plain. It has a relatively unbroken cover of vegetation. Discarded materials of military training (e.g., empty cans and shell casings) provided evidence of use but seemed to have little effect on the biota. A walking survey showed that 13 percent of the prairie was covered by tracks of various ages. This may be a high estimate since very few fresh tracks were on the Johnson Prairie. In addition, fossorial mole mounds tended to turn the soil, thus eliminating some tracks. Tracks were most evident as 10- to 20-mm depressions where a vehicle turned and the surface layer had been torn away. At the edge of the Johnson Prairie site were areas of high disturbance caused by tracked vehicles. In these areas, the "typical" Johnson Prairie species were replaced by weedy species. However, at the sampling site, there was little evidence of specific "track" flora -- i.e., weeds that grow best in the ruts left by tracked vehicles.

No woody perennials were in the sampling site. Scattered clumps of the introduced Scotch broom (Cytisus scoparius) grew nearby. As for the 13th Division Prairie, ten 1-m^2 quadrats were sampled for density, frequency, and biomass.

Recorded Historical Land Use

To establish the ecological condition of the Fort Lewis area before the Army began using it for vehicle training, the historical use of the area was examined. The recorded history for the sites studied dates to the period of the Hudson Bay Company and Fort Nisqually, which was built in 1833. The 13th Division Prairie site was part of the prairie used by the Puget Sound Agricultural Company, a division of the Hudson Bay Company. By the 1850s, the interior plains had been opened up to grazing and agriculture; about 5000 cattle and 16,000 sheep roamed the area between the Nisqually and Puyallup Rivers.[13] Maps of that period show sheep and cattle lots within 1.6 km of what is now the 13th Division study site.[14] By 1860, large herds of sheep and cattle were on the Charles Wren homestead -- about 1.6 km west of the 13th Division Prairie sampling area.[15] (Just 3 years earlier, August Kautz had said that the Wren homestead was at the outer edge of civilization.[16]) The Army permitted grazing on the 13th Division Prairie until 1975.* Even today there is some unauthorized grazing on this prairie.

[13] British and American Joint Commission for the Final Settlement of the Hudson Bay and Puget Sound Agricultural Companies, Part III, Miscellaneous (Washington, DC: McGill and Witherdon Printers, 1867).

[14] British and American Joint Commission for the Final Settlement of the Hudson Bay and Puget Sound Agricultural Companies, Photographs and Maps, Edward Lander Portfolio (Washington, DC: War Department, 1852-1865).

[15] T. Scheffer, "Wren's Lane Boasts Historical Background," The Tacoma Sunday Ledger-News Tribune (4 Jan 1959).

[16] G. F. Reese, "Nothing Worthy of Note Transpired Today," The Northwest Journals of August V. Kautz (Tacoma Public Library, 1978).

* Personal communication with James Stephenson of Fort Lewis, WA, 1979.

Recorded aboriginal uses of the land are incomplete. Smith states that in aboriginal times the prairie was covered with heavy grass, which furnished excellent pasturage.[17] Today, the prairie is dotted with stands of Douglas fir, and the soil is poor. According to Lang, American Indians either burned or encouraged natural fires on these prairie grasslands. This helped maintain the area's floristic connections with the grassland of eastern Washington.[18]

The Johnson Prairie site lies about 6.4 km southwest of the former Puget Sound Agricultural Company holdings. Maps showed scattered homesteads on prairies and rolling hills of fir and cedar with fern, salal, and hazel in the understory.[19] The area had been grazed and farmed, and the timber had been sold by the late 1800s and the early part of the 20th century. The historical land use for the Johnson Prairie can be considered similar to but less intense than that of the 13th Division Prairie.

[17] M. W. Smith, The Puyallup-Nisqually, Columbia University Contributions to Anthropology, Vol 32 (Columbia University Press, 1940).

[18] F. A. Lang, A Study of Vegetation Change on the Gravelly Prairies of Pierce and Thurston Counties, Western Washington (M.S. Thesis, University of Washington, 1961), pp 62-72.

[19] British and American Joint Commission for the Final Settlement of the Hudson's Bay and Puget Sound Agricultural Companies, Photographs and Maps, Edward Lander Portfolio (Washington, DC: War Department, 1852-1865).

3 METHODS

Mammals

Small mammal trapping at Fort Lewis was done on the two upland prairie sites: the 13th Division Prairie test and the Johnson Prairie control. Some trapping was also conducted at two riparian areas along Muck Creek: a test site next to and just east of the 13th Division Prairie, and a control site upstream, about 2500 m south and east of the riparian test. Trapping on the upland prairie was done from June 7 to 15, with 1389 trap nights on the test site and 1831 trap nights on the control. On the riparian sites, trapping was conducted June 5 through 7, 1979, with 250 trap nights on the test and 310 trap nights on the control.

Traps were set along line transects on the control and test sites, with individual traps spaced at about 10-pace (8- to 9-m) intervals. Generally, each trap line was baited for two consecutive nights. Then the traps were removed, and a new line was set out at another location in the same area. Snap traps were used and baited with a mixture of rolled oats and peanut butter.

Specimens captured were examined and measured for species identification, and skins and skulls were prepared for museum use. These specimens are now kept at the U.S. Army Construction Engineering Research Laboratory (CERL).

The capture results at these test and control sites were compared using a capture index -- which is the number of individuals of each species captured, divided by the number of trap nights, multiplied by 1000. Also, a Chi-square test was used to compare the populations of each species captured at the test and control sites. Further, comparisons were made of the biomass of each of these species and of the various species by guild (groups of organisms that use the same environmental resources in a similar manner).

Birds

The survey methods used in this study combined the procedures of Emlen, Severinghaus, and Balph, Stoddart, and Balph.[20] Biomass information (the number, or weight, of all organisms of a given designation in a specified habitat or region) was obtained by combining the information presented in Norris and Johnson, Behle, Graber and Graber, Esten, Baldwin and Kendeigh,

[20] J. T. Emlen, "Population Densities of Birds Derived from Transect Counts," Auk, Vol 88 (1971), pp 323-342; J. T. Emlen, "Estimating Breeding Bird Densities from Transect Counts," Auk, Vol 94 (1977), pp 455-468; W. D. Severinghaus, "Guidelines for Terrestrial Ecosystem Survey," Technical Report N-89/ADA086526 (CERL, May 1980); M. H. Balph, L. C. Stoddart, and D. F. Balph, "A Simple Technique for Analyzing Bird Transect Counts," Auk, Vol 94 (1977), pp 606-607.

Poole, Amadon, and Oberholser.[21] The bird survey was conducted from June 3 through June 17, 1979.

Vegetation

Botanical features measured were species composition, frequency (number of quadrats in which the species was encountered), mean density, absolute cover, and species richness. The ecological distance between stands is a measure of the overall similarity of composition in a prairie. This distance was calculated from cover data: high values indicate greater differences in species composition than low values.

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[21] R. A. Norris and D. W. Johnson, "Weights and Weight Variations in Summer Birds from Georgia and South Carolina," Wilson Bulletin, Vol 70, No. 2 (1958), pp 114-129; W. N. Behle, "Weights of Some Western Species of Horned Larks," Auk, Vol 60 (1943), pp 216-221; R. R. Graber and J. W. Graber, "Weight Characteristics of Birds Killed in Nocturnal Migration," Wilson Bulletin, Vol 74, No. 1 (1962), pp 74-88; S. R. Esten, "Birds Weights of 52 Species of Birds (Taken from Notes of William Van Goider)," Auk, Vol 48 (1931), pp 572-574; S. R. Baldwin and S. C. Kendeigh, "Variation in the Weight of Birds," Auk, Vol 55 (1938), pp 416-467; E. L. Poole, "Weights and Wing Areas in North American Birds," Auk, Vol 55 (1938), pp 513-518; D. Amadon, "Bird Weights and Egg Weights," Auk, Vol 60 (1943), pp 221-234; H. C. Oberholser, The Bird Life of Texas, 2 Vols (University of Texas Press, 1974).

4 RESULTS

Mammals

Six small mammal species from six different genera and four different guilds were captured during trapping at four sites. For each of these species, Table 1 provides information on the number of captives, by site, and gives the capture index for each species. The table also compares the changes in species population for the upland and riparian sites, and lists the results of a Chi-square test of distribution for each species on the upland and riparian sites.

On the upland prairie sites, the number of captures and the capture index values were higher for the wandering shrew, the Townsend vole, and the Pacific jumping mouse. The number of captures of deer mice were about equal on the two sites, but the capture index value was higher for this species on the test site. The capture index for all species on the upland control site was 20.8 and dropped to 18.7 on the test site.

On the riparian control site, the number of captures and the capture index were higher than on the upland control for the wandering shrew and Townsend vole, but lower for the shrew-mole and deer mouse. There were 20 percent fewer trap nights on the riparian sites than on the upland sites. But since there were many small mammals in the tall grasses and beneath the deciduous trees along Muck Creek, the overall capture index was 161.3 on the control and 96.0 on the test.

The Townsend mole, *Scapanus townsendii*, was not captured with surface snap traps. But its presence was confirmed by the many mounds of dirt that it characteristically throws up from its underground runways. These mounds were evident on both riparian sites and the upland control site, but not on the upland test site. To verify the species' presence, one individual was captured from the upland control area and one from the riparian test site. This species requires special traps, so more individuals were not captured; therefore, mole data were not included in the capture figure listed in Table 1.

Of the three small mammal species occurring most often on these glacial outwash prairies, both the wandering shrew and the Townsend vole had negative population changes on test versus control sites. The deer mouse, on the other hand, made population gains. On the upland prairie, those population differences were not significant beyond the $p = 0.5$ to 0.1 level. But on the riparian sites, the shrew populations were significantly different at the 0.005 level, and the deer mice populations at the 0.05 to 0.25 level.

The wandering or vagrant shrew, *Sorex vagrans*, has a range extending from Alaska to Southern Mexico. The subspecies occurring in Western Washington State, *Sorex vagrans vagrans*,[22] prefers moist habitats, generally at lower elevations.[23] These shrews, which eat soft-bodied insects, insect pupae, earthworms, and some seeds and soft vegetation, were abundant in the riparian

[22] W. W. Dalquist, *Mammals of Washington* (University of Kansas, 1948), p 136.
[23] E. J. Larrison, *Mammals of the Northwest* (Seattle Audubon Society, 1976) p 12.

Table 1

Mammal Capture Data

Set: Species	Capture				Capture Index				Change in Population		Chi-Square Test	
	Upland Control	Upland Test	Riparian Control	Riparian Test	Upland Control	Upland Test	Riparian Control	Riparian Test	Upland Control, Upland Test	Riparian Control, Riparian Test	Upland Control Upland Test	Riparian Control Riparian Test
					1831	1389	310	250				
Sorex vagrans Wandering shrew	14	8	46	15	7.6	5.8	148.4	60	-25%	-60%	P=0.5 to 0.1	p=<0.005
Peromyscus maniculatus Deer mouse	19	18	0	6	10.4	13.0	0	24	x1.25%	x100%	p=0.5 to 0.1	p=0.05 to 0.025
Microtus townsendii Townsend vole	3	0	4	1	1.6	0	12.9	4.0	-100%	-69%	p=0.9 to 0.5	p=0.5 to 0.1
Zapus trinotatus Pacific jumping mouse	1	0	0	0	.5	0	0	0	--	--	insufficient data	
Neurotrichus gibbsii Shrew mole	0	0	0	2	0	0	0	8	--	--	insufficient data	
Scapanus townsendii Townsend mole	1	0	0	(1)	--	--	--	--	--	--	--	
All species	38	26	50	24(1)	20.8	18.7	161.3	96.0				

sites. Shrew populations dropped rapidly, however, on the more xeric upland prairies, with the capture index falling from 60 on the riparian test to 5.8 on the adjoining upland prairie. Also, many of the shrews that were captured on upland sites were found in moist depressions and locally mesic areas that occurred on the undulating prairies.

On the upland prairies, the deer mice, Peromyscus maniculatus, replaced the vagrant shrew as the most abundant small mammal. Deer mice accounted for 50 percent of the small mammal captures on the upland control and increased to 69.2 percent of the captures on the upland test. On both riparian and upland sites, capture indexes for this species were higher on test than control sites, indicating the species' tolerance to training disturbance.

In Washington State, deer mice range from sea level to above timberline. According to Dalquist, these mice are "the commonest mammal encountered" in habitats ranging from the lowland marshes and deciduous thickets of western Washington, the coniferous forests and alpine meadows of the mountains, and even the deserts of eastern Washington.[24] Ingles notes that Peromyscus maniculatus in North America ranges over 1.295×10^7 km^2, with a wide variety of habitat.[25]

Deer mice are nocturnal and generally active throughout the year. They rest off the ground in trees or reeds; in thickets, grasses, or discarded material on the ground surface; and in burrows. If a nest or burrow of another mammal or bird is available, deer mice probably will adapt it to their needs. The diet of deer mice consists of seeds, nuts, berries, as well as some insects, mushrooms, and lichens.[26] Unlike Microtus, deer mice seldom eat grass, bark, or leaves, and their movement is generally not restricted to runways.[27]

Microtus townsendii, the townsend vole, ranges west of the Cascade Mountains from southern British Columbia into northern California.[28] This species prefers marshes and damp meadows, but also occupies drier grasslands. Except during the seasons when grasses and other vegetation are most abundant, and afford the greatest protection, these mammals restrict their movements to runways, which successive generations of voles may wear into ditches several inches deep. The diet of the Townsend voles, which are both diurnal and nocturnal, includes succulent leaves and stems of many grasses and forbs.[29] Like the shrews, vole populations declined on control versus test sites for both upland and riparian areas.

Two other species were captured from these sites, Zapus trinotatus, the Pacific jumping mouse, and Neurotrichus gibbsii, the shrew-mole. The single Pacific jumping mouse was captured on the upland control prairie in an open meadow near a clump of Douglas fir trees. Its range is similar to that of the

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[24] Dalquist, p 328.
[25] L. G. Ingles, Mammals of the Pacific States (Stanford University Press, 1968).
[26] Dalquist, p 329.
[27] Dalquist, p 329.
[28] W. H. Burt and R. P. Grossenheider, A Field Guide to the Mammals (Houghton Mifflin Co., 1976), p 190.
[29] Dalquist, pp 350-351.

Townsend vole, and among its habitats are "clearings in the forests in the Puget Sound area."[30] Seeds, grasses, and berries are the principal foods of the jumping mouse.

Two shrew-moles were captured on the riparian test in an area very close to Muck Creek. These burrowing mammals occur in moist ravines and along streams (up to an altitude of 2440 m) in northwestern California and through western Oregon and Washington. They feed on arthropods, annelids, and some vegetable matter, and usually move along subsurface runways, both by day and by night.[31] Not enough Pacific jumping mice and shrew-moles were captured to compare results for the control and test sites in the upland and riparian areas.

The Townsend mole, Scapanus townsendii, has a range in the western one-third of Washington and Oregon, extending south into northern California. It generally is found in field and meadows, but also occurs in the fir forests. Dalquist indicates that this mole is abundant on glacial outwash prairie.[32] Chiefly nocturnal, the mole moves underground almost all the time. In digging its tunnels, the Townsend mole throws up numerous mounds. Ingles reports that one mole can make several hundred hills during the rainy season. Its diet is over 75 percent earthworms, but it also eats roots, seeds, insects, insect larvae, and spiders.[33]

Because of this species' large biomass and conspicuous absence on the upland test area, the mole was included in biomass comparisons between upland sites. Including mole data in upland biomass comparisons and not in riparian biomass comparisons may have distorted the biomass data slightly. On the upland control, the location and frequency of mole mounds seemed to indicate the presence of more than one mole. Only one mole was captured in subsurface trapping, however, so only one mole was included in biomass comparison. If more than one mole was present on the control prairie, the impact of training activities on total biomass (as indicated in Figure 2) may have been greater than indicated in the biomass data.

On the other hand, mole mounds were evident on both riparian sites. Since mole population estimates at these sites were difficult to establish, mole biomass data were excluded from riparian test and control comparisons. If mole biomass data had been included, and populations of moles were about equal, the difference in total biomass between control and test sites (as indicated in Figure 3) might have been decreased.

The results of biomass comparison between test and control sites are indicated by species in Table 2, and by guild in Table 3. Of the three most common species, biomass decreased for wandering shrews and Townsend voles on both upland and riparian test sites, and increased for deer mice on both upland and riparian test sites.

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[30] Dalquist, p 371.
[31] Dalquist, p 126.
[32] Dalquist, p 126.
[33] L. G. Ingles, Mammals of the Pacific States (Stanford University Press, 1968).

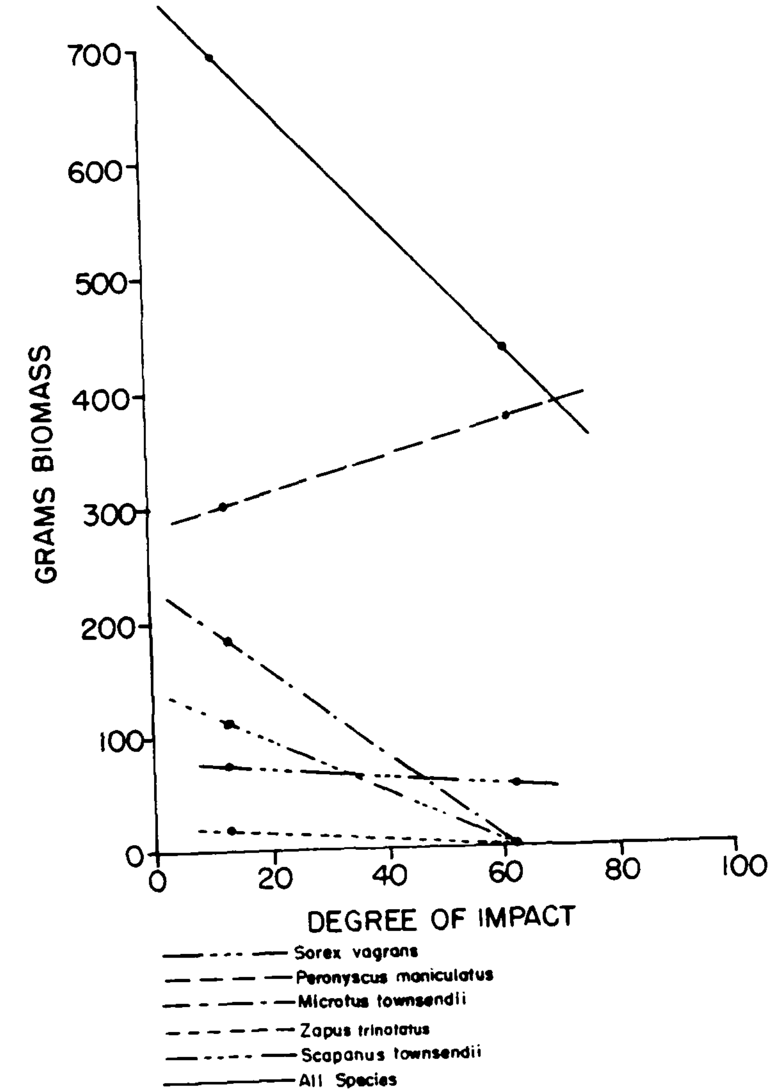

Figure 2. Upland prairie mammal biomass.

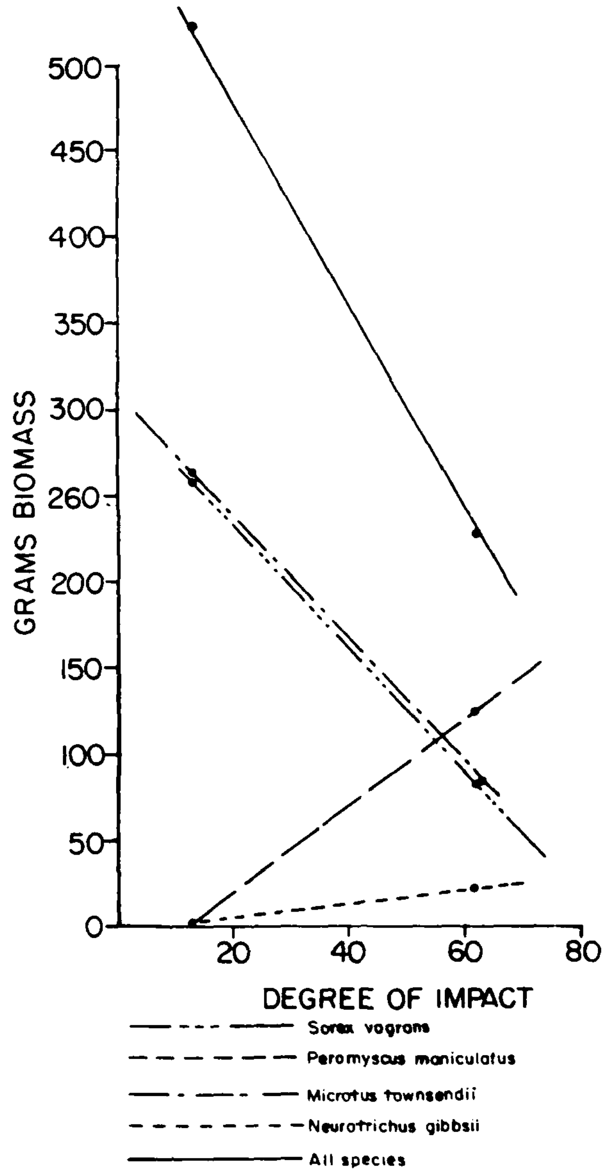

Figure 3. Riparian prairie mammal biomass.

Table 2

Biomass of Small Mammals

Species	Upland Control	Upland Test	Riparian Control	Riparian Test	Change, Upland Control/ Test	Riparian Control/ Test
Sorex vagrans	74.4	56	259.5	105	-25%	-60%
Permyscus maniculatus	302.8	378	0	126	x1.25	x100
Microtus townsendii	184.4	0	261.1	81	-100%	-69%
Zapus trinotatus	19.7	0	0	0	-100%	--
Neurotrichus gibbsii	0	0	0	22	--	+100%
Scapanus townsendii	111.6	0	--	--	-100%	--
Totals	692.9	434	520.6	229	-37%	-56%

Table 3

Mammal Guild Biomass

Guild No. and Members	Guild Description	Upland Control	Upland Test, % Decline	Riparian Control	Riparian Test
1. Moles	subterranian, nonaerial, insectivorous, carnivorous, small	107	0 (100%)	--	--
2. Shrews	surface nonaerial, insectivorous, carnivorous, small	74.4	56 (25%)	259.5	104 (60%)
7. Voles, Lemmings, Cotton Rats	runway dwellers, grass eaters, herbivorous, small	197	0 (100%)	261.1	81 (69%)
12. White Footed Mice, Harvest Mice, Jumping Mice	nest dwelling, secretive, seed eaters, herbivorous, small	322.5	378 (x1.17)	0	126 (x100)

In CERL Special Report N-77, nonmarine mammals were grouped into 30 guilds.[34] The six small mammal species captured at Fort Lewis represent four of these guilds, as Table 3 indicates.

When biomass is compared by guild for control and test sites, there is a decrease in both riparian and upland test sites for guilds 1, 2 and 7, and an increase in both riparian and upland test sites for guild 12 (Figure 4).

Birds

Twelve species of birds were observed on the 13th Division and Johnson Prairies. Of these, only 10 species can be considered residents (Table 4). One "nonresident," a great blue heron, flew across the transect line and landed along Muck Creek about 2 km northwest of the test site. The second nonresident was a white rock dove that had escaped during dog field trials which had been conducted about 1 km north of the test. The heron, like the dove, was seen only during one observation period.

The data for birds were analyzed by examining total biomass and diversity, and by using guild theory.[35]

Because it eliminates the variations between habitat types and concentrates on the amount of sustainable life that is present, total biomass is the most accurate measure of the overall effect tracked vehicle training has on bird populations. Biomass was totaled for both the test site (15 682.1 g/100 ha) and the control site (19 664.5 g/100 ha). The biomass data were then graphed (Figure 5) against the amount of soil surface disturbance previously analyzed. If one assumes that change in biomass per amount of disturbance is a linear relationship, this graph can be used to estimate the projected amount of avian biomass with 0 to 100 percent disturbance (Table 5). The percentage lost (38 percent) was well within the range found previously at Fort Knox, KY; from 20.9 percent for a short-term site (less than 1 year), to 59.8 percent for a long-term use site (over 45 years).[36]

The change in diversity between the two sites was expected, with four species being found on both test and control, two species only on the test, and four species only on the control. The four species occupying both the test and the control were the barn swallow, American robin, western meadowlark, and savannah sparrow. Of these four, only the American robin showed a significant preference for the control ($p < 0.005$); the other three preferred the control, but the difference was not significant. The two species seen only on the test site were the horned lark and the starling; both were observed in significant numbers ($p < 0.005$ and $0.05 > p > 0.025$, respectively). This is not surprising because the starling is an introduced species which prefers open areas around man and his dwellings, while the horned lark

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[34]W. D. Severinghaus, R. E. Riggins and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA073782 (CERL, July 1979), p 59.

[35]Severinghaus, Riggins, and Goran. W. D. Severinghaus, "Guild Theory Development as a Mechanism for Assessing Environmental Impact," Journal of Environmental Management, Vol 5, No. 3 (1981), pp 187-190.

[36]Severinghaus, Riggins, and Goran.

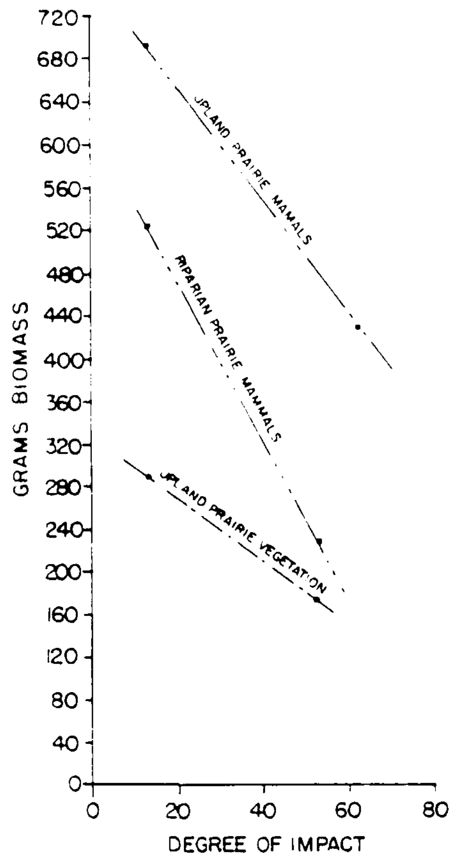

Figure 4. Biomass comparisons.

Table 4

Avian Density and Biomass

	Test		Control	
	No./100 ha	Biomass (g)	No./100 ha	Biomass (g)
Common flicker*			25.2	3528.0
Horned lark*	75.5	2642.5		
Barn swallow	1.4	29.4	2.5	52.5
Common crow			1.2	557.6
American robin*	15.7	1208.9	42.9	3303.3
Starling*	19.7	1516.9		
Western meadowlark	38.3	3753.4	45.7	4478.6
American goldfinch			5.5	77.0
Savannah sparrow	311.0	6531.0	358.9	7536.9
White-crowned sparrow			5.0	150.6
Totals	461.6	15 682.1	486.9	17 664.5

*Indicates species for which a statistical significance occurs between test and control at the p = 0.05 level.

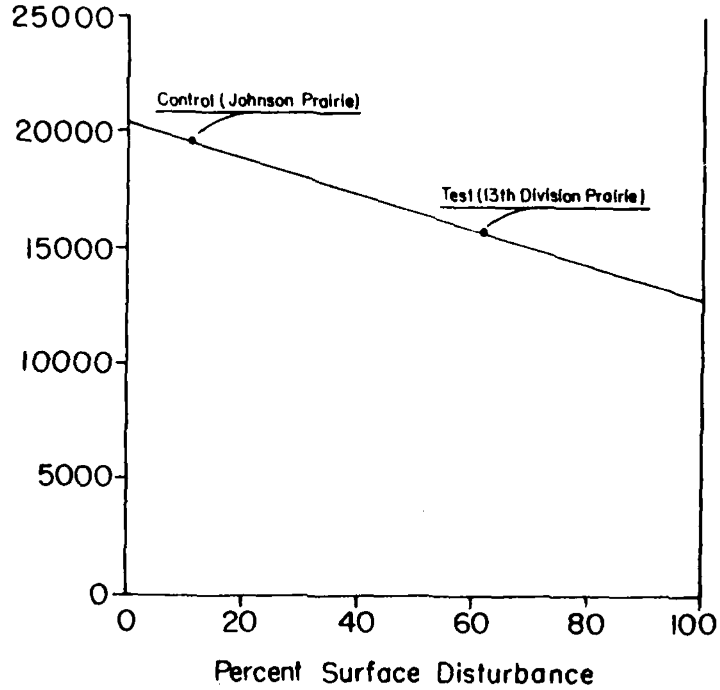

Figure 5. Bird biomass versus percent disturbance.

Table 5

Projected Bird Biomass

Percent Soil Surface Disturbance	Biomass (Grams/100 ha)	Percent Loss
0	20 500	---
13	19 660	4.1
62	15 680	23.5
100	12 750	62.2

"is one of the very few songbirds which seeks for its feeding habitat not woodlands, not brushlands, not grasslands, but bare ground."[37] The four species observed only on the control were the common flicker, common crow, American goldfinch, and white-crowned sparrow. Of these, only the common flicker showed a significant preference for the control ($0.025 > p > 0.01$).

The feeding habits of the common flicker, American robin, and western meadowlark may be affected by tactical vehicle activity. All three species prefer to feed on the ground and on a variety of large, nonflying invertebrates. The population of these birds may have been reduced, in part, because food resources were lost when vehicles compacted the soil. The lack of the American goldfinch and white-crowned sparrow on the test site may have resulted from two interdependent causes: their normal low population levels, since they generally prefer brushy thickets, and their relative intolerance of human disturbance.

CERL also applied guild theory to assess bird populations at Fort Lewis. Guild theory maintains that species belonging to the same guild use resources similarly. When this theory is used to analyze environmental change, two products should result. First, as negative or positive changes within each species are combined with other species of the same guild, the cause of the changes should become more evident. Second, as the causal relationships are determined and the quantity of basic data increases guild by guild, the cause/effect relationships between man and his environment become more predictable.

The bird data from Fort Lewis were tabulated following the guild scheme in Table 6.[38] The important points to note are the guild characteristics, the *direction of change (+ or -), the percent change, and the probable cause of* the change. Of the 11 guilds on which data were gathered, two -- the great blue heron and rock dove -- were questionable and were not included in Table 6. Guild 1 was divided into two separate guilds to correct incompatibilities in habitat requirements. The major negative effects (1A, 3, 11, 28, 29, 30) were the general degradation of the prairie and loss of food for nonherbivores, while the positive effects (1B, 31) were caused by degradation or loss of vegetation and general disturbance.

Vegetation: Johnson Prairie

Table 7 shows species composition, frequency (number of quadrats in which the species was encountered), mean density, and absolute cover percentage for Johnson Prairie species. Total mean cover averages 161 percent (the total exceeds 100 percent because of overlapping layers). Mean density is 600 individuals per square meter. Nonvascular plants are not counted in these density figures. Note that for grass species, density figures are not accurate and, at best, refer to stems, not individuals.

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[37] H. C. Oberholser, The Bird Life of Texas, Vol II (University of Texas Press, 1974), p 568.

[38] W. D. Severinghaus, "A System for Predicting Biological Impact," Journal of Environmental Management, Vol 5, No. 3 (1981), pp 187-190.

Table 6

Avian Guild Analysis

Guild	Primary Characteristics	Guild Test	Biomass Control	Percent Biomass Change	Probable Cause of Change
1A	Seedeating, open field	6531.0	7536.9	-13.3	Degradation of prairie
1B	Seedeating, bare ground	2642.5	---	+100.0	Reduction in vegetation
3	Seedeating, edge	---	127.6	-100.0	Reduction of prairie margins
11	Insectivorous, sustained diurnal	29.4	52.5	-44.0	Reduction in suitable habitat for food source
28	Omnivorous, open field	3753.4	4478.6	-16.2	Degradation of prairie
29	Omnivorous, mixed ground	1208.9	6831.3	-82.3	Compaction of soil causing loss of food source
30	Omnivorous, mixed nonground	---	537.6	-100.0	Degradation of prairie
31	Omnivorous, disturbed sites	1516.9	---	+100.0	Disturbance of prairie

Table 7

Mean Cover, Density, and Frequency of Species in Johnson Prairie

	Species	Frequency	Average Cover, Percent	Average Density
1.	Camassia quamach +	7	0.67	2.70
2.	Festuca idahoensis +	3	20.50	96.00
3.	Hypericum perforatum &	5	0.55	2.50
4.	Thlaspi arvensis *	8	0.98	10.10
5.	Hypochaeris radicata &	10	18.64	45.60
6.	Plantago lanceolata &	9	5.66	22.00
7.	Trifolium procumbens &	7	0.94	8.50
8.	Ranunculus californica +	6	0.90	11.70
9.	Holcus lanata &	9	6.87	37.50
10.	Cerastium arvense +	5	0.37	8.80
11.	Poa pratense &	9	23.19	96.90
12.	Eriophyllum latatum +	9	6.70	57.40
13.	Danthonia californica (?) +	5	1.0	6.10
14.	Moss, unk. #	5	8.80	
15.	Cladonia sp. #	4	4.65	
16.	Polytricum juniperinum #	9	11.30	
17.	Rumex acetosella *	5	0.29	2.70
18.	Chyrsanthemum leucanthemum &	4	4.50	40.20
19.	Balsamorhiza deltoidea +	1	4.00	.30
20.	Sisyrinchium douglasii +	1	0.01	0.10
21.	Aster curtus +	5	4.56	36.50
22.	Lomatium triternatum +	1	0.01	0.10
23.	Viola howellii %	4	0.07	0.70
24.	Lomatium utriculatum +	8	4.23	22.70
25.	Rhacomitrium canescens	6	16.50	
26.	Lupinus spp. (?) &	1	0.50	0.10
27.	Microseris sp. (?) +	4	0.41	2.40
28.	Carex pensylvanica +	5	7.58	34.80
29.	Crepis capillaris (?) *	4	0.53	1.30
30.	Aira caryophyllea *	2	0.03	1.10
31.	Unknown moss #	1	0.02	0.20
32.	Archillea millefolium +	5	1.12	13.00
33.	Lolium perenne &	1	0.06	0.60
34.	Bromus mollis *	4	5.70	32.60
35.	Trifolium pratense &	1	0.10	0.10
36.	Vicea sativa &	1	0.02	0.20
37.	Veronica sp. *	2	0.25	2.50
38.	Potentilla recta &	1	0.03	0.30
39.	Senecio jacobea &	1	0.10	0.40
		Mean Frequency= 4.564	Absolute Cover= 4.16	Mean Density= 17.10

Key
* = introduced annuals; & = introduced perennials; + = native perennials;
# = nonvascular plant; ? = uncertain due to taxonomic confusion; % = native annual.

The Johnson Prairie is dominated by a variety of species. Festuca idahoensis dominates three quadrats strongly, but is absent from the rest. Hypochaeris, Plantago lanceolata, Holcus lanata, Poa pratensis, Polytricum juniperinum (moss) and Rhacomitrium canescens are the major species. Dominants are mainly introduced perennials in the herb layer and native nonvascular plants in the ground layer. The prairie resembles the Mima Mounds Prairie in its species composition.[39]

The biomass of the Johnson Prairie averages 288 + 132 g/m^2 (Table 8), a rather low figure for standing crop in an ungrazed meadow. The value suggests low fertility, caused by a combination of earlier agriculture and low initial nutrient capital on these shallow glacial outwash soils. Summer drought and frequent disturbances may also account for the low figure. There is essentially no bare ground (1.8 percent average, but lacking entirely in seven plots), suggesting that there has not been disturbance at least in the last year.

The overall frequency measures the homogeneity of the prairie. If each species occurred in every plot, the frequency would be 100 percent. In fact, mean frequency is 45.6 percent. Ten species occur; but only one, Hypochaeris, is in every plot. The mean distance between quadrats is 0.56. When the individual values are inspected, the impression that quadrats 1, 2, and 3 are very different from the remaining seven is confirmed. The mean distance between 1 and 3 is 0.28, while the mean distance to the other seven quadrats is 0.71.

The Johnson Prairie data were ordered by several techniques that resulted in generally similar configurations of quadrats in species-defined space. Figure 6 shows the computer-generated results of the best of these configurations (judged on the basis of interpretability and freedom from distortion). This graph was produced using reciprocal averaging (RA) on log-transformed cover data. Figure 7 shows the computer-generated results of RA using log-transformed density data (which omits nonvascular plants). Logarithmic transformations are generally recommended with cover data. The transformation reduces the effects of large values and increases the validity of qualitative changes -- that is, changes in species composition. All species were used in the analysis.

There are two distinct quadrat groups (Figures 6 and 7). Plots 1 to 3 are clearly separate from the rest, which are arrayed on the second computer-generated axis. Because of a high concentration of Rhacomitrium, plot 8 is an extreme for the cover ordination (Figure 6). In the density plots, where Rhacomitrium is not included, plots 4 and 9 are also extremes.

Table 9 presents the matrices of the quadrats, or stands, by species for cover and density data. The values are expressed as deciles, based on the matrix maximum. This means that the highest value in the matrix is set to 9, and other values are scaled so that values between 1 and 10 percent of the maximum are converted to + (plus), values from 11 to 20 percent are given 1, and so forth. A - (minus) means the species was not present.

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[39] R. Del Moral and D. Deardorff, "Vegetation of the Mima Mounds, Washington State," Ecology, Vol 57 (1976), p 520.

Table 8

Biomass for Johnson and 13th Division Prairies

	Biomass (g/m^2)	
Sample	Johnson Prairie	13th Division Prairie
1	268.5	216.3
2	445.6	234.6
3	574.6	267.8
4	216.8	---
5	261.4	126.9
6	142.1	130.9
7	241.3	107.5
8	343.0	245.1
9	186.6	73.5
10	197.1	163.5
Mean	287.7	173.9

*Data collected from 1-m^2 quadrats by the harvest method, overdried at 38°C for 24 hours. Johnson Prairie harvested June 11, 1979; 13th Division Prairie harvested June 8, 1979.

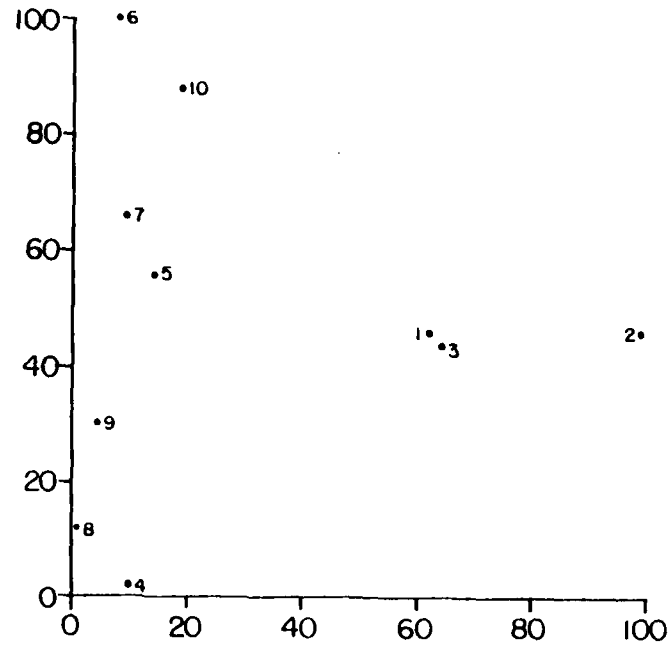

Figure 6. Johnson Prairie log-transformed cover data.

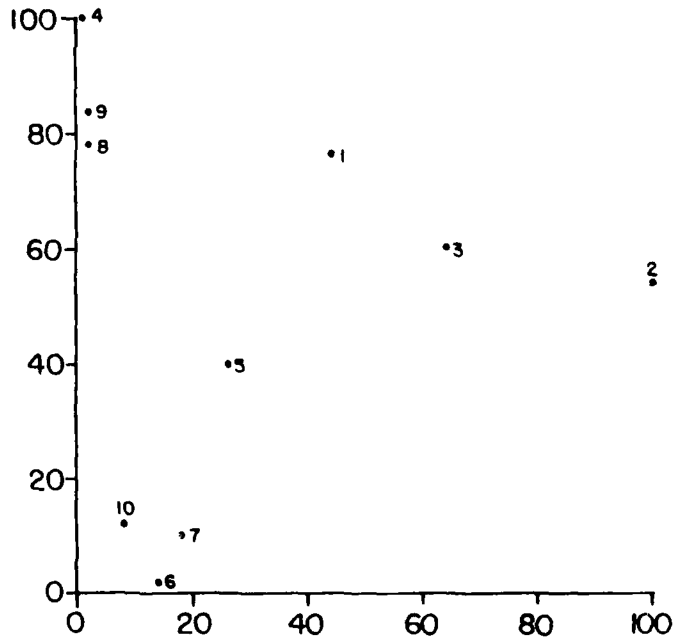

Figure 7. Johnson Prairie log-transformed density data.

Table 9

Stand-by Species Ordination Results for the First RA Axis: Johnson Prairie

The quadrats and species are arranged in the optimum order. Data are decile scores. Species numbers are from Table 7.

Cover Data

Species	Quadrats
	000 0001000
	231 5940876
20	+-- -------
22	+-- -------
19	4-- -------
2	598 -------
14	322 --1+---
3	+++ ----++-
23	+++ ---+---
21	11- 1----++
15	--1 2--1-+-
16	1+1 +5+111-
12	-1+ 2+++1++
5	2+1 242+411
4	+-+ -++++++
25	-2- 221-82-
18	+-- +----3+
6	+++ +1+1-+1
33	--- +------
8	-++ +++-+--
24	-++ +++2-++
1	+++ +-+-++-
7	+-+ -++-+++
13	-++ -++--+-
17	--+ -++-++-
28	--- 14+-2-+
9	+-+ 211++1+
30	--- -++----
27	--- +-++--+
26	--- --+----
31	--- --+----
11	-++ 2+83514
32	--- ++-+-++
10	--+ +--+-++
34	--- ---4+++
29	--- +-+++--
38	--- -----+-
39	--- -----+-
37	--- -----++
36	--- ------+
35	--- ------+

Density Data

Species	Quadrats
	000 0001000
	132 5647809
2	977 -------
19	--+ -------
20	--+ -------
22	--+ -------
23	+++ -----+-
3	+++ ---++--
21	-12 4+-+---
5	1+1 21++1+1
6	+++ +2++-++
33	--- +------
12	+1- 61++2++
24	++- +1++-11
4	+-+ -+1++++
1	+++ +-+++--
18	--1 ++-8---
27	--- +++--+-
13	++- --++--+
10	+-- +1-+-+-
9	+-+ 1+++1+4
11	++- 242264+
17	+-- --+++-+
35	--- -+-----
36	--- -+-----
7	+-+ -++++-1
8	++- +-+-+-2
31	--- --+----
26	--- --+----
37	--- -+-+---
29	--- +-+-++-
28	--- 1++-2-5
32	--- ++-1-++
38	--- ---+---
39	--- ---+---
34	--- -2-+13-
30	--- --+---+

The table shows the order of stands in the first and most informative computer-generated axis, and the order of species in this same axis. Species toward the top of the table are those more abundant in the quadrats to the left of the "Quadrat" column. Note, therefore, that an ideal distribution will have the modal distributions found along the diagonal of the matrix in Table 9. Again, there are two distinct groups. Quadrats 1 to 3 are characterized by Festuca, Viola, and Sisyrinchium, three native species. In contrast, native species such as Carex, Achillea, and Cerastrium occur primarily in the other seven quadrats. The weedy introduced species occur throughout.

The data in Table 10 show the absence of Fritillaria lanceolata and Dodecatheon hendersonii from the six 50-m^2 plots sampled at the 13th Division Prairie. Viola howellii was present in 50 percent of the plots. However, it was always on the tops of mounds, and was never found in depressions between mounds or on extended flat areas. A tentative interpretation suggests that the greater tracked vehicle activity at the site affected these three species.

Vegetation: 13th Division Prairie

Table 11 provides species composition, frequency, mean cover percentage, and mean density data for the 13th Division Prairie. Total cover is 122.4 percent, substantially less than the Johnson Prairie. There is more bare ground than at Johnson Prairie, though the exact amount was not recorded. Density is high, averaging over 1050 stems per plot, reflecting a large dominance by grasses. Biomass is 174 g/m^2, a 40 percent reduction from the Johnson Prairie data. This decrease in biomass is certainly associated with the mechanical disturbance by tracked vehicles. However, the history of grazing is also related to these low values. The mean of 174 g/m^2 places the 13th Division Prairie below the lowest estimates for biomass on temperate grasslands although one-half the values fall above Whittaker's 200 g/m^2 lower limit.[40]

Average frequency is 40 percent, lower than at Johnson Prairie. The mean distance between quadrats in this prairie is 0.55, similar to that of the Johnson Prairie (0.56), but no distinct clusters were identified. When results from the two prairies are combined, the mean distance between each quadrat in one prairie and each quadrat in the other is 0.64. Thus, the two prairies are floristically distinct.

Figure 8 shows the distribution of quadrats resulting from an RA ordination of log-transformed cover data. Quadrats 8, 9, and 10 are extremes, while the rest are fairly similar.

Figure 9 shows the distribution of quadrats resulting from the RA analysis of density. Only quadrat 8 is isolated, primarily on the basis of having Luzula, Plantago major, and Campanula.

Table 12 summarizes cover and density by quadrat, as identified in the ordinations. (The table is read like Table 9.) Introduced species dominate this prairie. The ordinations for cover and density are similar.

[40] R. H. Whittaker, Communities and Ecosystems (The Macmillan Company, 1970).

Table 10

Presence of Three Disturbance-Sensitive Prairie Species on the Johnson and 13th Division Prairies

Site	Sample	Species*		
		Fritilleria	Dodecatheon	Viola
Johnson Prairie	1	2	1	9
	2	14	14	7
	3	1	1	6
	4	1	1	36
	5	0	1	1
	6	4	19	7
13th Division Prairie	1	0	0	0
	2	0	0	1
	3	0	0	46
	4	0	0	0
	5	0	0	15
	6	0	0	0

*Individual Fritilleria lanceolata, Dodecatheon hendersonii, and Viola howelii were counted in $50m^2$ quadrats.

Table 11

Mean Cover, Density, and Frequency of Species in the 13th Division Prairie

	Species	Frequency	Average Cover, Percent	Average Density
1.	Eriophyllum lanatum +	6	3.80	65.40
2.	Hypochaeris radicata &	9	11.00	67.90
3.	Plantago lanceolata &	10	9.30	
4.	Festuca idahoensis +	6	8.04	89.60
5.	Bromus mollus *	8	4.28	108.20
6.	Rumex acetocella *	2	0.04	3.10
7.	Hypericum perforatum &	5	0.34	9.90
8.	Thlaspi arvensis *	3	0.06	1.70
9.	Polytricium juniperinum #	87	2.40	
10.	Rha comitrium canascens #	8	42.60	
11.	Holcus lanatus &	8	1.94	29.60
12.	Aria caryophyllea *	5	3.05	142.60
13.	Carex pensylvanica +	8	2.34	42.80
14.	Festuca bromioides *	5	1.62	125.60
15.	Zigadenus venenosus +	2	0.02	0.20
16.	Campanula rotundifolia +	2	0.08	6.90
17.	Viola howellii &	1	0.01	1.00
18.	Koeleria cristata +	3	0.57	7.70
19.	Poa pratensis &	8	15.20	173.80
20.	Moss sp. #	3	12.00	
21.	Caryophyll &	1	0.10	2.00
22.	Lupinus sp. (?) &	3	0.70	1.00
23.	Chrysanthemum leucanthemum &	2	0.09	0.90
24.	Panicum scribnerianum (?) +	1	0.01	0.10
25.	Teesdalia nudicaulis *	1	0.01	0.10
26.	Luzula sp. +	1	0.11	1.10
27.	Taraxicum officinale *	2	1.59	9.30
28.	Trifolium pratensis &	1	0.01	0.10
29.	Festuca bromioides	1	1.00	45.30
30.	Plantago major *	1	0.20	2.90
31.	Camassia quamash +	1	0.02	0.20
	MEAN	4.000	3.95	37.75

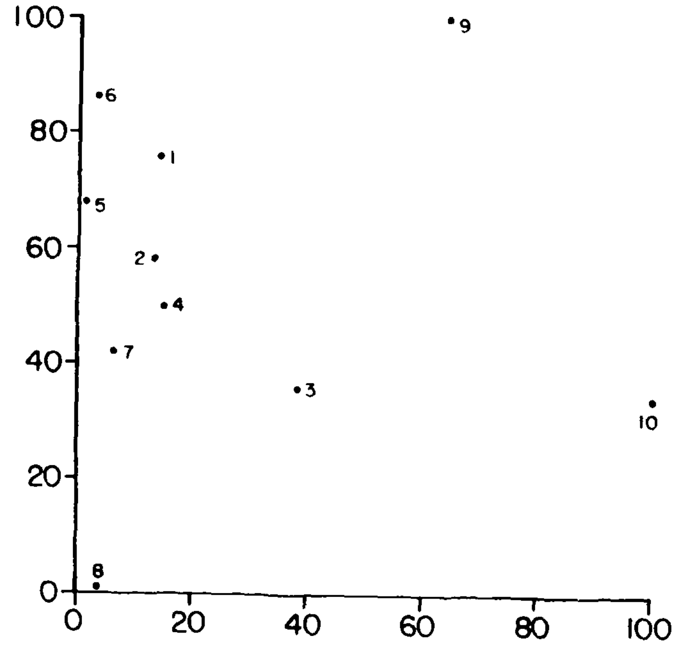

Figure 8. 13th Division Prairie log-transformed cover data.

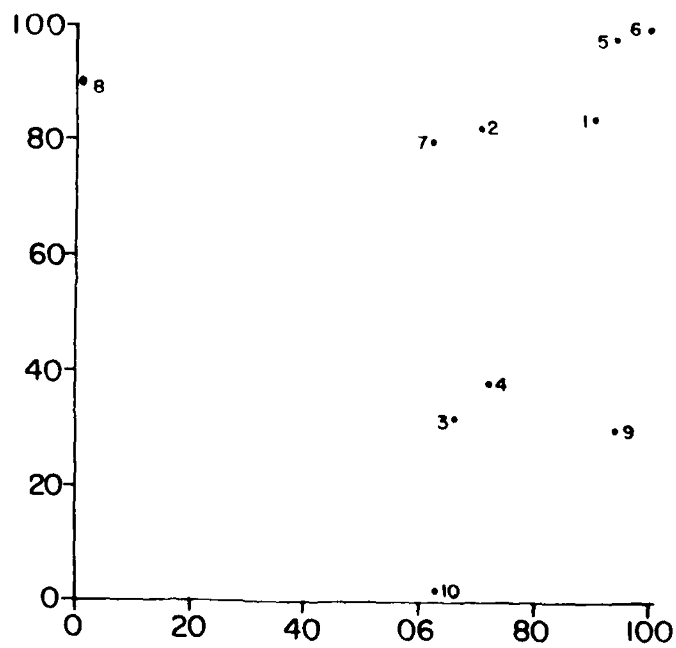

Figure 9. 13th Division Prairie log-transformed density data.

Table 12

Stand-by Species Matrices for the First Ordination Axis of RA
Using Cover and Density Data: 13th Division Prairie

The quadrats and species are arranged in the optimum order. Data are decile scores. Species numbers are from Table 11.

Cover Data

Species	Quadrats
	0000000001
	5862174390
24	+---------
23	+-+-------
26	-+--------
30	-+--------
16	-+-+------
8	+-+-+-----
22	++---+----
15	-+-+------
14	+-+++-+---
17	---+------
31	---+------
6	+---+-----
9	+++-++++--
7	-+++++----
11	+-+++++++-
10	+4289+67--
25	-----+----
21	------+---
2	++1111+1+-
3	1+21++++++
4	---11+++2-
12	+-+-++--+-
18	------++-+
13	+-+++-++++
5	-++++-++2+
19	++--++1342
1	-+-++-++-1
29	--------+-
28	--------+-
27	--------+1
20	-------+18

Density Data

Species	Quadrats
	0010000000
	8703241596
26	2---------
30	3---------
16	4---2-----
15	+---+-----
22	21-----+--
1	5-85252---
25	-1--------
7	25--1-3--1
19	5997-5344-
18	--14-1----
2	59-4333434
3	6453533635
17	----2-----
31	----1-----
21	----1-----
27	--7-----2-
4	-2-5453-4-
11	-4-3341414
13	--53332443
5	+-21424-55
14	----4+42-6
6	------2+--
12	-1----4445
24	-------+--
28	--------+-
29	--------5-
8	------+2-1
23	-------2-1

Presence of Disturbance-Sensitive Vegetation

Three native herbaceous plants -- checkerlily (Fritillaria lanceolata), broad leaved shooting star (Dodecatheon hendersoni), and Howell's violet (Viola howellii) -- are sensitive to disturbance.* Thus, the presence of these plants would suggest that the prairie vegetation is relatively undisturbed.** Individuals of these three species often are scattered widely within the prairie community. Only one of the three, Howell's violet, appeared in any of the 1-m^2 plots at the Johnson Prairie and 13th Division Prairie sites.

To compensate, larger plots, 50 m^2, were sampled specifically for these three species. Table 10 shows that in five of the six samples, all three species were present. The data are tentative, and suggest only that the Johnson Prairie site does support populations of plants that are sensitive to the types of disturbance created by tracked vehicles.

Species Characteristics

Tables 7 and 11 provide general information about the species encountered. Introduced species dominate both prairies, but to different degrees.

In the Johnson Prairie, the total cover of introduced species is 64.5 percent. The cover of native vascular plants is 56.6 percent, and of nonvascular plants 41.3 percent. In contrast, on the 13th Division Prairie, the mean cover of introduced species is 49.9 percent, while that of natives is 15.5 percent, and of nonvascular natives 57.0 percent. Thus, introduced species occupy a greater proportion of the total in the 13th Division Prairie; native vascular plants are poorly represented. Nonvascular plants are not adversely affected as a group, but the lichens are absent. Species such as Festuca, Carex, and Camassia are present, but drastically reduced from their dominance on Johnson Prairie and in less disturbed prairies such as the Mima Mounds. The absence of Cladonia, a lichen extremely sensitive to trampling or motorized disturbance during the dry season,* suggests that the 13th Division Prairie has indeed been heavily disturbed.

In contrast, the mosses readily recover from disturbance and are not destroyed by a few episodes of trampling. Furthermore, they are not subject to competition from introduced species which might occupy their ecological niche.

Comparison of the Ordinations

The cover data from both prairies were combined to determine directly the differences between the two prairies. Species with only one occurrence were deleted to make interpretation easier and to reduce beta diversity. Table 13 shows the combined quadrat-by-species list that results from this analysis. Quadrats 1 through 10 are from the Johnson Prairie, quadrats 11 through 20 are

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* Personal communication with R. Del Moral of the Department of Botany, University of Washington, 1979.

**Personal communication with M. Denton of Department of Botany, University of Washington, 1979.

from the 13th Division Prairie. Note that, except for quadrat 8, samples from the two prairies are distinct. This conclusion is strengthened when the quadrat ordination is studied. The main distinctions are readily seen. Unknown moss (species 14, Table 7) Aster curtus, Cladonia, Danthonia, Trifolium procumbens, Lomatium utriculatum, Ranunculus californicus, Veronica sp., and Crepis are confined to the Johnson Prairie, while Zigadenus, Campanula, Viola, Moss Sp. (species 20, Table 11), and Taraxacum are confined to the 13th Division Prairie. The 13th Division Prairie is dominated by generalist species common also in the Johnson Prairie, while Johnson Prairie dominants are often reduced in the 13th Division Prairie. This, too, suggests that the 13th Division Prairie has been disturbed more than Johnson Prairie; has suffered substantial reductions in species, biomass, cover, breadth; and has been dominated more by weeds.

Figure 10 shows the distribution of the 20 quadrats resulting from RA ordination of log-transformed cover values. There is a strong hump, as would be expected when two distinct samples are combined. In essence, two separate ordinations are extractible in this graph. The Johnson Prairie stands are bounded by stands 2 and 8 on a gradient that is nearly vertical, while the 13th Division Prairie stands are bounded by 15 and 20 on an axis that goes from the upper left to the middle right. Both of these axes have been marked on the graph. The ordinations are similar to those when the plots were run individually by prairie.

Figure 11 displays species ordination, reinforcing the results of Table 13. Species that dominate Johnson Prairie are found in the lower left, while species dominant in the 13th Division Prairie are found to the right. Species with similar distributional patterns occur in the same region of this graph. Species common to both prairies occur in the midregions of Figure 11. Figures 10 and 11 are structurally similar because they are, in fact, interrelated.

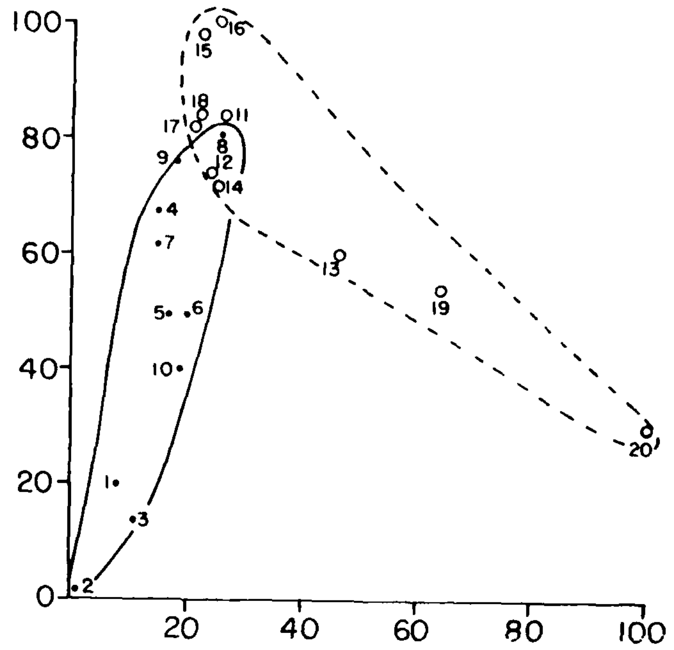

Figure 10. Combined cover data (solid circles = Johnson Prairie, open circles = 13th Division Prairie).

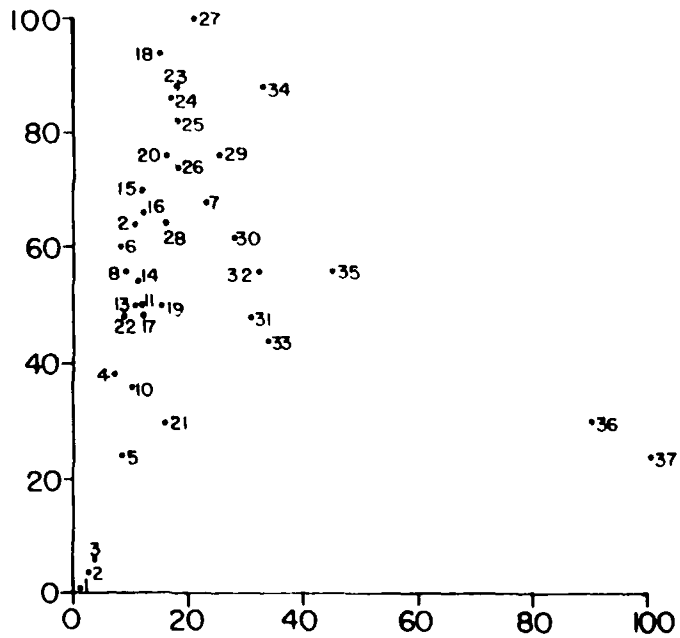

Figure 11. Combined cover data by species (numbers refer to Table 7).

Table 13

Reciprocal Averaging Ordination of Combined Quadrats
From the Fort Lewis Prairies

Species	Quadrats*
	00000001011110111112
	21374950675828461390
Moss (species 14, Table 7)	645-3--2------------
Aster curtus	5-3+--3-2-----------
Viola howellii	+++----+----+-------
Chrysanthemum leucanthemum	3--3--1-2-1----+----
Cladonia sp.	-3-+--33------------
Danthonia californica	-++1+1--------------
Trifolium procumbens	++-++2--+----+------
Thlaspi arvensis	+1-+2+-++-+--+-++---
Hypericum perforatum	12++-----2-1++-++---
Lomatium utriculatum	-11++2142-----------
Microseris sp.	----1-+++-----------
Ranunculus californica	-++-+2+------1------
Achillea millefolium	---1-1+1+-----------
Polytricium juniperinum	432214+3-214-233+1--
Rumex acetosella	-+-+++----+--+--+---
Camassia quamash	++++1-+-----+1------
Veronica sp.	---+----1-----------
Lupinus sp.	----2---241---------
Cerastium arvense	-+-+--++1-----1-----
Holcus lanatus	++-3323+214-1232+++-
Festuca idahoensis	767------+--5-4-434-
Hypochaeris radicata	54+2433239444444442-
Campanula rotundifolia	-----------1+-------
Zigadenus venosus	-----------++-------
Crepis capillaris	----+-++-----2------
Rhacomitrium canescens	--43333--619747566--
Festuca bromioides	----------+-1-+32---
Plantago laneolata	+121+21332844-153123
Carex pensylvanica	----+33-+-3-2312+13+
Bromix mollis	---1---42--+12+22+4+
Eriophyllum lanatum	-231+1322--4331-13-6
Poa pratense	-+1351345611-45-2557
Vicia sativa	--------+---------+-
Aira caryophyllea	----++---++----33-3-
Koeleria cristata	--------------+--2-+
Moss sp. (species 20, Table 11)	-----------------349
Taracicum officiale	------------------25

*Data are log-transformed cover. Species that occurred only once were eliminated. Quadrats 1 through 10 = Johnson Prairie, quadrats 11 through 20 = 13th Division Prairie.

5 DISCUSSION

Vegetation

The vegetation of the Johnson and 13th Division Prairies probably was quite similar at one time, and was certainly more similar than now. The differences may relate to substantially greater disturbance on the 13th Division Prairie. Johnson Prairie is less disturbed, as shown by its higher species richness, greater cover, greater biomass, reduced dominance by introduced species, the occurrence of *Cladonia* in the 1-m^2 quadrats, and the presence of *Aster curtus*, a threatened species.* The Johnson Prairie also shows greater consistent internal structure (beyond structure spuriously obtained because of sampling error); quadrats 1, 2, and 3 are clearly distinct from the others. These quadrats are either less disturbed or more moist than the others.

Also, the presence of *Fritillaria lanceolata* and *Dodecatheon hendersonii* in 50-m^2 quadrats on the Johnson Prairie and their absence on the 13th Division Prairie show the former site to be less disturbed than the latter. The greater frequency of *Viola howellii* and its less restricted distribution on the Johnson Prairie support these findings.

Birds

The tracked vehicles training on Fort Lewis has caused about a 25-percent loss of bird biomass in areas used most. Generally, this fits the results seen in other ecological systems. The second most important result is the change in diversity. The number of species stayed relatively the same, six and eight, but only four species were found in common between the test and control. Training caused a reduction or loss of the sensitive, pure grassland, or prairie species, and a gain in less sensitive and disturbed site species.

Additional changes in bird species should not be expected unless Fort Lewis begins to use its training areas more, or opens new areas. The major problem would be the continued loss of some of the more sensitive and habitat-restricted species, whose existence in the general area would be threatened.

The general effect of tracked vehicle training activities on bird populations is a loss in biomass and a change in diversity. The almost 40 percent loss in avian biomass was expected, as was the increase in the biomass and numbers of species that prefer disturbed sites -- starlings and horned larks, for example. The change in diversity was not as extreme as that in areas of the United States where normally closed canopy forests are opened (southern coniferous forests and hardwood forests). This shift was probably not as great because areas that were prairie before training returned to the same state after training. The major problem for the bird population was the

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* Source: in-house files of endangered, threatened, and endemic plant taxa for Pierce County and Thurston County Washington, Building 17, Airdustrial Center, Olympia, Washington.

reduction of food resources because of soil compaction. This eliminated many of the invertebrate fauna that the American robin and common flicker need.

Mammals

For the three most commonly captured mammal species -- the wandering shrew, the deer mouse, and the Townsend vole -- the response to increased tactical vehicle activity, as determined by comparing control to test sites, was similar on both upland and riparian sites. This similarity is illustrated in the "All Species" slopes of Figures 2 and 3. Increased tactical vehicle activity affected shrews and voles negatively and deer mice positively. While these trends were similar on upland and riparian sites, statistical differences (at the $p = 0.05$ level) between populations on control and test sites occurred only on the riparian sites, and only for the wandering shrews and the deer mice.

Data were insufficient to indicate population trends in response to vehicle activities for the three other species encountered -- the Townsend mole, the Pacific jumping mouse, and the shrew-mole. However, judging from the presence or absence of mounds, the Townsend mole apparently tolerated vehicle activity on the deeper depressional soils along Muck Creek (riparian test site), but not on the more shallow, rocky upland outwash soils of the 13th Division prairie (upland test site).

A comparison, by guilds, of captured species' biomass, indicates that the mole guild was negatively impacted on the upland, but not on the riparian test. The shrew and vole guilds were negatively affected on both upland and riparian sites. The white-footed mouse guild was positively impacted on both the upland and riparian sites. Except for the mole on the riparian test site -- where two shrew-moles were captured in a locally undisturbed shrub thicket near Muck Creek) -- these results correlate closely with those predicted as a result of similar research at Fort Knox, KY.[41]

From the Fort Knox research, it was predicted that tracked vehicle disturbance would have a negative and extensive impact on the den-nest-cover parameter for the mole, shrew, and vole guilds, and a positive and moderate impact on the white-footed mice guild. The predicted impact of tracked vehicle disturbance on the food parameter was negative and extensive for the mole guild, negative and moderate for the vole guild, and negative and minimal for the white-footed mice guild. The soils, climate, and vegetation at the Fort Lewis sites and the Fort Knox sites were quite different, and different species represented the mammal guilds. Yet the impacts of tracked vehicle activity, as predicted by the way in which these groups of organisms use the same environmental resources, were essentially the same.

One exception to the predicted impacts occurred with the mole guild on the riparian site. While two shrew-moles' presence on the riparian test was confined to a locally undisturbed area, the Townsend mole's mounds were evident even in areas where the ground surface was disturbed. Yet these mounds

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[41] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA073782 (CERL, July 1979), p 49.

were absent from disturbed upland areas. Since this mole's activities are almost entirely subterranean, differences between the upland and riparian soils probably affect the species' tolerance to disturbance. The riparian soil (Norma fine sandy loam) is high in fertility, moderately deep, and high in moisture storage capacity, while the upland soil (Spanaway gravelly sandy loam) is low in fertility, moderately shallow, and droughty. When mechanically disturbed, the riparian soil more rapidly recovers vegetative cover and more continuously sustains food and burrowing resources than similarly disturbed upland soils.

Increasing vehicle disturbance of the ground generally decreases moisture at the surface, at the shallow subsurface level, and through the herbaceous vegetative strata. The wandering shrew, the Townsend vole, and the Townsend mole, prefer moist conditions. The shrew-mole and the Pacific jumping mouse also prefer moist habitats, and are likely also to be negatively affected by vehicle disturbance; however, the evidence from captures was not adequate to confirm this observation. The den-nest-cover and food parameters for each of these species are negatively affected by the increasingly xeric conditions and the concurrent reduction of vegetative cover caused by tactical vehicle disturbance. The 40 percent reduction in vegetative biomass between upland test and control has a particularly negative effect on the runway-dwelling, grass-eating Townsend vole. The low fertility of undisturbed upland prairie soils supports only patches of adequate cover for this species. With over 60 percent of the ground surface disturbed, the crushing and uprooting action of vehicle training results in a herbaceous layer too sparse to protect and support the vole.

On the other hand, the seed-eating, nest-dwelling, and climbing deer mice are apparently able to adapt to the changes resulting from tactical vehicle disturbance. In studies at other locations, deer mice and other species of the genus _Peromyscus_ maintained or increased their population levels on sites affected by tracked vehicles.[42] Ingles refers to _Peromyscus_ as a "genetically pliable genus" because of the wide range of environmental circumstances to which species of this genus adapt.[43] Of the several species of _Peromyscus_ in North America, the deer mice are the most wide ranging and the most adaptive.

One of the reasons that deer mice can tolerate the impact of vehicle turbance is that they are primarily seed eaters. When the herbaceous stra... is disturbed, as on the upland prairies at Fort Lewis, there is a shift from perennial grasses to high-seed-producing annual weeds.

While some deer mice naturally occur on the outwash prairies at Fort Lewis, the population in undisturbed areas may be quite low. No deer mice were captured from the riparian control, and almost half of the 19 deer mice captured from the upland control were found near a disturbed, weedy area, used occasionally as a runway, close to the center of the prairie.

[42]Severinghaus, Riggins, and Goran; W. D. Severinghaus and W. D. Goran, _Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, Texas_, Technical Report N-113 (CERL, September 1981).

[43]L. G. Ingles, _Mammals of the Pacific States_ (Stanford University Press, 1979), p 259.

6 CONCLUSIONS

1. This report has described preliminary indications of ecological differences between selected Army tracked vehicle training areas and areas undisturbed by training. This study indicated that at Fort Lewis there was about a 40 percent loss of vegetation, and that there was little damage from erosion. The bird population also suffered a 40 percent loss in biomass, with only a small change in diversity.

2. The procedures used to obtain the field data and analyze this information proved efficient and effective.

3. This report has analyzed Fort Lewis' ecosystem to verify tactical vehicle cause/effect relationships examined in other ecosystems. The results from this gravel moraine prairie were generally comparable to information obtained previously.

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